FAUNAL DIVERSITY OF CLADOCERA (CRUSTACEA: BRANCHIOPODA) OF LOKTAK LAKE (A RAMSAR SITE), MANIPUR (N.E. INDIA)

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Plankton samples collected from Loktak lake (a Ramsar site) during November 2002-October 2004 revealed 51 species of Cladocera belonging to 28 genera and 7 families. Loktak lake holds the richest Cladocera biodiversity known from any individual aquatic ecosystem of India, so far. The cladoceran fauna is characterized by predominance of Chydoridae > Daphniidae, Cosmopolitan > Cosmotropical species, general tropical character, dominance of littoral-periphytic taxa and lack of seasonal periodicity of occurrence of different families or species. Richness varies between 22-42 (29 ±5) and 20-41 (28 ±5) species and, records 51.7-82.33% and 53.6-90.0% community similarities (*vide* Sorenson's index) during two years respectively. It exhibits identical trimodal annual patterns with maxima during winter and minima during monsoon. ANOVA registers significant temporal variations in richness of Cladocera between months and insignificant between years. Richness is inversely correlated with water temperature, rainfall, pH, hardness, nitrate, chloride and total dissolved solids, and is positively correlated with dissolved oxygen. Multiple regression analysis indicates moderately higher cumulative influence of fifteen abiotic factors on richness.

Key words: Ramsar site, Loktak lake, Cladocera, biodiversity, distribution, temporal variations

INTRODUCTION

Cladocera, an important group of fish-food, and an integral component of meta-zooplankton, have been reported from scattered localities from different states of India since 1860s. There is, however, limited information on their diversity in different aquatic ecosystems, particularly flood plains, of India (Sharma and Sharma 2008a). Investigations on Cladocera diversity of 'Ramsar sites' of India are so far restricted to Deepor beel (Sharma and Sharma 2008b, 2009), one of the largest floodplain wetlands of Assam (N.E. India), and wetlands of Keoladeo National Park, Rajasthan (Venkataraman 1992).

Loktak Lake, a Ramsar site, and one of the largest natural freshwater lakes of eastern India, is under severe environmental stress because of serious habitat degradation, influx of waste water, and encroachment of land for agriculture and human settlements. Attempts are being undertaken to manage this biologically, environmentally and socio-economically important floodplain wetland of South Asia. Little is known about the micro-faunal diversity of Loktak lake in general, and that of Cladocera in particular; the information on the later is limited to a preliminary unpublished list of Shyamananda Singh (1991).

The present study, the first detailed systematic account of Cladocera of Loktak lake, is therefore significant. Observations were made to determine species composition, temporal variations in richness, and community similarities of these micro-crustaceans. The nature and composition of the cladoceran taxocoenosis are discussed. Remarks are made on occurrence and distribution of various interesting elements and on influence of the abiotic factors on Cladocera richness.

MATERIAL AND METHODS

The present study forms a part of a limnological survey of Loktak lake, Bishnupur / Imphal districts, Manipur, undertaken from November 2002-October 2004 (24° 25'-24° 42'N; 93°46'-93°55'E; area: 286 sq. km; max. depth: 4.58 m; altitude: 768.5 m above msl). This floodplain wetland is characterized by floating mats of vegetation called *Phumdi*, which are inhabited by the endangered Brow-antlered Deer (*Cervus eldii eldii*). The common aquatic plants of this lake include *Eichhornia crassipes*, *Hydrilla verticellata*, *Euryale ferox*, *Vallisneria spiralis*, *Utricularia flexuosa*, *Trapa natans*, *Lemna trisula*, *Pistia striates*, *Salvinia* sp., *Nymphaea* spp., *Nymphoides* spp., *Nelumbo mucifera*, *Potamogeton* spp. and *Azolla pinnata*.

Plankton samples were collected seasonally from different parts of Loktak basin (during November 2002-October 2004) by towing a nylobolt plankton net (mesh size: 50 µm). In addition, water and plankton samples were collected regularly every month, during the study period at Sendra (24° 30'56.75"N; 93°47'45.61"E). All the plankton samples were preserved in 5% formalin.

Water samples were analyzed for various abiotic factors following standard methods (APHA 1992), while water temperature, specific conductivity, pH, and dissolved oxygen

were recorded with field probes. Qualitative plankton samples were screened; Cladocera species were isolated and were identified following the works of Smirnov (1971, 1976, 1992, 1996), Michael and Sharma (1988), Korovchinsky (1992), Sharma and Sharma (1999, 2008a) and Orlova-Bienkowskaja (2001).

Percentage similarities between monthly cladoceran communities were calculated *vide* Sorenson's index and were analyzed by hierarchical cluster analysis (SPSS version 10). The significance of temporal variations of richness was ascertained *vide* ANOVA. Ecological importance of individual abiotic factors was studied *vide* simple correlation coefficients (r). Multiple regression analysis was undertaken to analyze cumulative influence of fifteen abiotic factors, namely water temperature, rainfall, pH, conductivity, dissolved oxygen, free CO_2, alkalinity, hardness, nitrate, phosphate, sulphate, silicate, chloride, dissolved organic matter and total dissolved solids.

RESULTS AND DISCUSSION

Abiotic parameters

Mean water temperature affirms sub-tropical range of Loktak lake. Specific conductivity indicates low ionic concentrations (Table 1) and warrants inclusion of this Ramsar site under 'Class I' category of 'trophic classification' of Talling and Talling (1965). Slightly acidic and soft waters of this floodplain wetland depict moderate dissolved oxygen, low free CO_2, low concentration of micronutrients and other abiotic factors (Table 1).

Table 1: Abiotic factors of Loktak lake

Parameters	Range	Mean ± SD
Water Temp. (ºC)	14.2-28.5	21.8 ±4.2
Rainfall (mm)	0.0-480.0	138.2 ±154.8
pH	5.70-6.92	6.31 ±0.32
Sp. Cond. (µS/cm)	66.0-132.0	93.3 ±17.1
Dissolved Oxygen (mg/l)	4.2-9.0	5.7 ±1.1
Free CO_2 (mg/l)	6.0-13.0	9.2 ±2.0
Alkalinity (mg/l)	10.0-41.2	19.1 ±7.1
Hardness (mg/l)	24.0-54.0	38.3 ±7.8
Calcium (mg/l)	5.4-15.7	9.8 ±2.7
Magnesium (mg/l)	2.0-8.6	5.4 ±1.9
Sodium (mg/l)	0.6-7.5	4.8 ±2.0
Potassium (mg/l)	2.0-9.2	5.9 ±1.0
Phosphate (mg/l)	0.12-0.32	0.22 ±0.10
Nitrate (mg/l)	0.25-0.42	0.32 ±0.04
Sulphate (mg/l)	0.54-0.99	0.86 ±0.12
Silica (mg/l)	7.42-12.70	10.1 ±1.4
Chloride (mg/l)	10.0-20.1	15.8 ±3.0
DOM (mg/l)	0.7-2.1	1.34 ±0.39
TDS (mg/l)	0.16-0.81	0.44 ±0.19

Cladocera composition and distribution

51 species of Cladocera belonging to 28 genera and 7 families, examined from Loktak lake (Table 2) reflect a rich biodiversity of this group known from a floodplain lake, or aquatic ecosystem of the Indian subcontinent. The rich faunal diversity indicates greater environmental heterogeneity of this Ramsar site and re-affirms recent remarks (Sharma 2009) on the biodiversity of Rotifera of this wetland. The recorded species comprise about 40.9% of the Indian freshwater Cladocera. The present report also assumes special importance in view of a conservative estimate of occurrence of up to 60-65 Cladocera species in tropical and subtropical environs of India (Sharma and Michael 1987; Sharma 1991). Our results, however, present a distinct contrast to only 12 species listed earlier from Loktak (Shyamananda Singh 1991).

The richness of Cladocera recorded at Loktak is higher than that reported from Deepor beel (45 species) (Sharma and Sharma 2008b). The generic diversity at Loktak is marginally lower than that of Deepor (30 genera), while species composition of these two Ramsar sites indicate 75% similarity (*vide* Sorenson index), indicating occurrence of several common species. The richness at Loktak is higher than the 30 species reported from 30 wetlands of Keoladeo National Park (Venkataraman 1992), 36 species from 20 wetlands of South-eastern West Bengal (Khan 2003), 11 species from 2 floodplain lakes (Khan 1987) of Kashmir, 9 species from 65 wetlands of 24-Parganas district (Nandi *et al.* 1993) of West Bengal, 12 species (Sanjer and Sharma 1995) from floodplains of Bihar, and 14 species from 37 floodplain lakes (Sarma 2000) of Assam.

Of the biogeographically interesting species recorded from Loktak was *Disperalona caudata* – an Australasian species earlier known to occur only in Thailand and Australia; it was recently reported from India from Deepor beel (Sharma and Sharma 2007). *Simocephalus acutirostratus* may also be assigned as an Australasian species as it is known with certainty only from Australia and South-East Asia (Orlova-Bienkowskaja 2001). *S. heilongjiangensis*, another interesting species, has been often confused with its geographical vicariant *S. latirostris*; this generalization is also true for all earlier Indian reports, including those of Michael and Sharma (1988). The erroneous identification of *S. mixtus* with its geographical vicariant *S. vetulus* holds parallel with the earlier example both in taxonomic status as well as its earlier Indian reports. *S. vetulus* was previously assumed to be a cosmopolitan species, but the monographic revision of genus *Simocephalus* (Orlova-Bienkowskaja 2001) reveals its European and North African distribution, while *S. mixtus* is distributed in Asia, Eastern Europe, North Africa and North America (Yoon and Kim 2000). Amongst other interesting

species, *Diaphanosoma senegal* is a Palaeotropical species, *Sida crystallina* and *Picripleuroxus laevis* are notable Palaearctic elements, while *Camptocercus uncinatus* is an interesting recent addition (Sharma 2008) to the Indian Cladocera. In addition, *Alonella clathratula*, *Alona davidi*, *A. globulosa*, *A. guttata*, *Ceriodaphnia laticaudata*, *Chydorus faviformis*, *C. ventricosus*, *Dadaya macrops*, *Guernella raphaelis*, *Kurzia longirostris*, *Macrothrix odiosa* and *Pseudochydorus globosus* are examples of regional distributional interest.

The cladoceran taxocoenosis of Loktak lake depicts general tropical character with greater richness of Cosmopolitan > Cosmotropical species, and presence of several Circumtropical and Pantropical species. These salient features are further endorsed by occurrence of the Circumtropical genera *Dadaya* and *Guernella* and, the Pantropical *Ephemeroporus* though a number of the remaining genera are known for their cosmopolitan or worldwide distribution (Dumont and Negrea 2002). The cladoceran communities are characterized by dominance of littoral-periphytonic species, particularly of the families Chydoridae, Macrothricidae, Sididae and Ilyocryptidae. Our collections, however, exhibit fewer limnetic taxa belonging to Daphniidae, Bosminidae and Moinidae. The dubious listing of three species of *Daphnia* by Shyamananda Singh (1991) is misleading and warrants confirmation, as the euplanktonic genus *Daphnia* is known for its restricted distribution, as well as paucity of species in N.E. India (Sharma 1991).

Cladocera richness

Cladocera comprise the second most important group of zooplankton of Loktak contributing significantly in

Table 2: Systematic list of Cladocera from Loktak lake

Phylum : **Arthropoda**
Super-class : **Crustacea**
Class : **Branchiopoda**
Super-order : **Cladocera (*s. str.*)**

Order: **Ctenopoda**
Family: **Sididae**
Diaphanosoma excisum Sars, 1885
D. sarsi Richard, 1895
D. senegal Gauthier, 1951
Pseudosida bidentata Herrick, 1884
Sida crystallina (O.F. Müller, 1776)

Order: **Anomopoda**
Family: **Daphniidae**
Ceriodaphnia cornuta Sars, 1885
C. laticaudata P.E. Müller, 1867
Scapholeberis kingi Sars, 1901
Simocephalus (*Echinocaudus*) *acutirostratus* (King, 1853)
S. (*Coronocephalus*) *serrulatus* (Koch, 1841)
S. (*Simocephalus*) *mixtus* Sars, 1903
S. (*Simocephalus*) *vetuloides* Sars, 1898
S. (*Aquipiculus*) *heilongjiangensis* Shi & Shi, 1994

Family: **Bosminidae**
Bosmina longirostris (O.F. Müller, 1776)
Bosminopsis deitersi Richard, 1895

Family: **Moinidae**
Moina micrura Kurz, 1874

Family: **Macrothricidae**
Guernella raphaelis Richard, 1892
Macrothrix laticornis (Fischer, 1857)
M. odiosa (Gurney, 1907)
M. spinosa King, 1853
M. triselialis (Brady, 1886)

Family: **Ilyocryptidae**
Ilyocryptus spinifer Herrick, 1882

Family: **Chydoridae**
Subfamily: **Chydorinae**
Alonella clathratula Sars, 1886
A. excisa (Fischer, 1854)
Chydorus faviformis Birge, 1893
C. sphaericus (O.F. Müller, 1776)
C. ventricosus Daday, 1898
Dadaya macrops (Daday, 1898)
Disperalona caudata Smirnov, 1996
Dunhevedia crassa King, 1853
Ephemeroporus barroisi (Richard, 1894)
Picripleuroxus laevis Sars, 1862
P. similis Vavra, 1900
Pseudochydorus globosus (Baird, 1843)

Subfamily: **Aloninae**
Acroperus harpae (Baird, 1834)
Alona affinis (Leydig, 1860)
A. costata Sars, 1862
A. davidi Richard, 1895
A. globulosa (Daday, 1898)
A. guttata Sars, 1862
A. intermedia (Sars, 1862)
A. monacantha Sars, 1901
A. quadrangularis (O.F. Müller, 1776)
A. rectangula Sars, 1862
A. verrucosa (Sars, 1901)
Euryalona orientalis (Daday, 1898)
Camptocercus uncinatus Smirnov, 1973
Karualona karua (King, 1853)
Kurzia longirostris (Daday, 1898)
Leydigia acanthocercoides (Fischer, 1854)
Oxyurella singalensis (Daday, 1898)

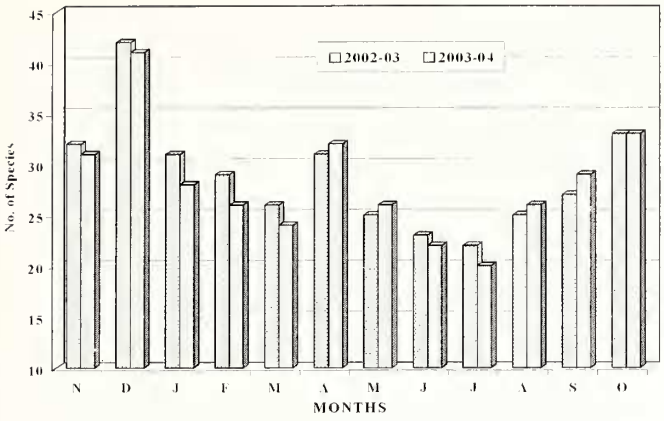

Fig. 1: Temporal variations in Species richness of Cladocera

richness (r = 0.877) and, hence, concur with their composition in beels of the Brahmaputra river basin (Sharma and Sharma 2008a,b). All the 51 species recorded from Loktak were observed in the samples collected during the first year, while only 47 species were recorded in the following year. Monthly richness (22-42, 29 ±5; 20-41, 28 ±5 species) exhibits identical annual ranges and mean values, and follows identical trimodal annual patterns (Fig. 1) with maxima during winter and minima during monsoon; the former aspect is affirmed by an inverse correlation between richness and water temperature (r = -0.512). Further, winter annual peaks of Loktak Cladocera correspond with those of Deepor beel (Sharma and Sharma 2008b) while monsoon minima differ from summer minima of the Deepor beel. ANOVA registers significant temporal variations in richness between months ($F_{11, 23}$ = 10.371, $p < 0.005$), but records insignificant annual variations. Richness records significant inverse correlations with rainfall (r = -0.562), pH (r = -0.504), hardness (r = -0.658), nitrate (r = -0.564), chloride (r = -0.627), and total dissolved solids (r = -0.785), and is positively correlated with dissolved oxygen (r = 0.443). Multiple regression registers moderately higher cumulative influence of 15 abiotic factors (R^2 = 0.703) on Cladocera richness while step-wise regression re-affirms importance of rainfall, pH, hardness, nitrate, chloride and total dissolved solids.

The Chydoridae, the most diverse family of Cladocera, contributes dominantly (29 species, 16 genera) to the faunal diversity in Loktak and broadly concurs with the qualitative role observed in Deepor beel (Sharma and Sharma 2008b). The chydorid richness varies between 13-21 and 12-23 species

Table 3: Percentage similarities (Sorenson's index) of Cladocera (2002-03)

Months	Nov	Dec	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct
Nov	-	78.3	73.0	65.6	65.5	66.7	66.7	69.1	74.1	70.1	64.4	76.9
Dec		-	78.9	67.6	67.6	74.0	65.7	58.5	59.4	65.7	72.5	74.7
Jan			-	80.0	70.2	67.7	67.8	66.7	64.1	66.7	65.5	75.0
Feb				-	76.4	70.0	70.4	61.5	62.7	74.1	71.4	70.1
March					-	65.5	58.8	53.1	62.5	82.3	71.7	70.1
April						-	64.3	66.7	52.8	67.8	68.9	75.7
May							-	55.2	59.6	68.0	73.1	68.9
June								-	54.5	51.7	64.0	71.4
July									-	68.1	53.0	65.1
Aug										-	73.1	75.0
Sept											-	70.0
Oct												-

Table 4: Percentage similarities (Sorenson's index) of Cladocera (2003-04)

Months	Nov	Dec	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct
Nov	-	75.0	78.0	80.7	80.0	88.7	73.4	71.7	70.6	80.7	90.0	71.9
Dec		-	69.5	62.3	64.6	76.7	68.6	63.5	62.3	68.6	77.7	81.8
Jan			-	70.3	65.4	73.3	70.4	76.0	83.3	70.2	80.7	72.1
Feb				-	72.0	79.3	69.2	70.8	69.5	76.9	80.0	77.9
March					-	78.6	80.0	53.6	72.7	80.0	79.2	77.2
April						-	72.4	74.1	65.4	79.3	81.9	76.9
May							-	66.7	73.9	80.8	80.0	71.1
June								-	80.9	62.5	66.7	69.1
July									-	78.2	75.5	71.7
Aug										-	80.0	77.9
Sept											-	77.4
Oct												-

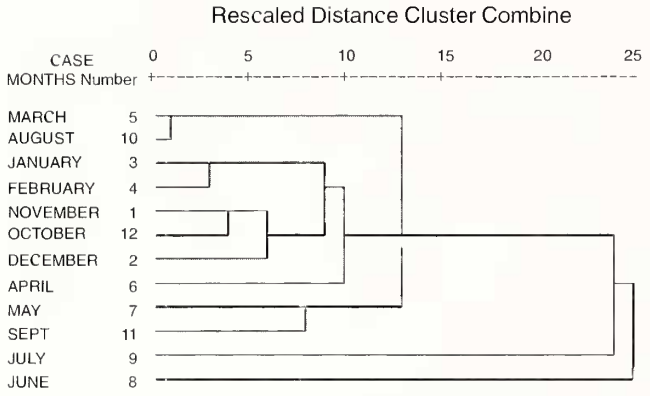

Fig. 2: Dendrogram showing Hierarchical cluster analysis of Cladocera (2002-03)

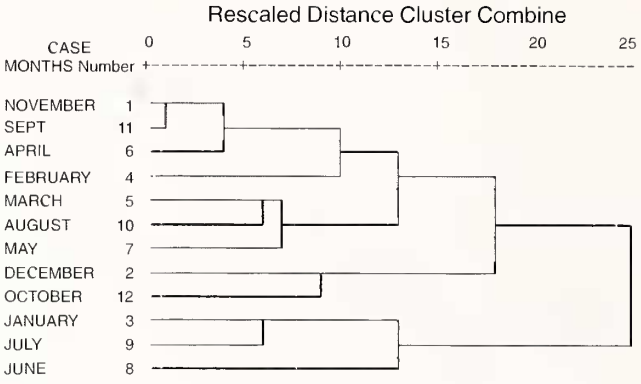

Fig. 3: Dendrogram showing Hierarchical cluster analysis of Cladocera (2003-04)

in two years respectively, follows trimodal annual patterns of monthly richness and show lack of any seasonal periodicity. The Chydorids register significant temporal variations between months ($F_{11, 23} = 11.944$, $p < 0.005$) and insignificant between years. They register significant inverse correlations with rainfall ($r = -0.423$), hardness ($r = -0.499$), chloride ($r = -0.433$), and total dissolved solids ($r = -0.664$) while multiple regression registers moderate cumulative influence of 15 abiotic factors ($R^2 = 0.573$) in their richness.

Cladocera community similarities

The cladoceran communities indicate (Tables 2 and 3) similarities (*vide* Sorenson's index) ranging between 51.7-82.3% during first year of the study period and a marginally higher range (53.6-90.0%) in the following year. The ranges broadly concur with the reports of Sharma and Sharma (2008a,b) in the floodplain lakes of Brahmaputra river basin of Assam state. A majority of instances (47.0%) in the matrix, however, indicate similarities between 60-70% during 2002-03, while it ranges between 70-80% in majority of instances (60.6%) during 2003-04. Higher similarity values may be attributed to more perennial or nearly perennial species, and fewer rare species occurring in limited monthly samples during each year. The cluster analysis (Figs 2 and 3) exhibits variations in faunal composition of Cladocera during both the years. Our results show (Fig. 2) more closeness of cladoceran communities between March and August, and again between January and February while June and July collections indicate greater differences in their composition during the first year (November 2002-October 2003). In the succeeding year (November 2003-October 2004), greater closeness (Fig. 3) is noticed between November and September (peak similarity), while the samples collected during December and June indicate greater differences in their species composition.

To sum up, the Cladocera of Loktak are characterized by varied taxocoenosis, occurrence of various species of global or regional distributional importance, significant monthly variations of richness, qualitative dominance of littoral-periphytonic taxa, and paucity of euplanktonic species. The results show lack of seasonal periodicity of occurrence of a number of species belonging to different families as well as of individual species. Various abiotic factors exert limited influence individually on Cladocera richness. On the other hand, higher cumulative influence is observed as a number of these factors are also interdependent.

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